INTERNATIONAL SOLDIER SYSTEMS CONFERENCE AND EXHIBITION 2004

Development of Nonwoven Fabrics for Military Applications

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The Science Behind the Warrior: Yesterday, Today and

Background:

- **Four major attempts to use nonwoven fabrics.**
  - 1985- Tentage
  - 1995- Disposable Chemical Protective booties
  - 1997- Humanitarian Parachutes
  - 2001- Barbed / Razor Wire resistant gloves

- Current military nonwoven usage limited to fusibles for dress coats, shirts, battle-dress uniforms, rainwear and various rainwear end-items.

Abstract:

- **United States Marine Corp**
  - Small Business Innovative Research Contract (SBIR)
    - Phase I, 6 mo. $ 70 K , Proof of Concept
      - 3 mo option, $30 K, interim to Phase II
    - Phase II, 24 mo. $600 K + 6 mo. Option for $150 K, rapid fruition of technology
    - Phase III, requires joint funding partners geared toward manufacturing

- **Phase I awarded to Nanosyntex, Morristown, TN**
  - Developed proprietary nonwoven composite fabrics
  - Used various fibrous webs to impart numerous characteristics & hand
  - Lighter in weight, more breathable, superior tear and break properties
  - Enhances durability, wash resistance
  - Composite design allows different internal vs external

Purpose:

- **Review USMC SBIR Phase I Development Contract**

- **Primary Contractor Award:**
  - Nanosyntex, Vasanth Narayanan, Ph.D.
    303 N. Fairmont Ave. Suite 201
    Morristown, TN 37814

Goals:

- To develop and incorporate enhanced nonwoven composite fabrics for military uniforms, heavy-duty shelter and equipage applications.
- Nanosyntex proposed development of a composite nonwoven military uniform fabric that possesses high strength, softness, improved abrasion resistance, printability and other related characteristics.
- Key was that Nanosyntex stressed that there is no Off-The-Shelf nonwovens available and a new product needed to be engineered.

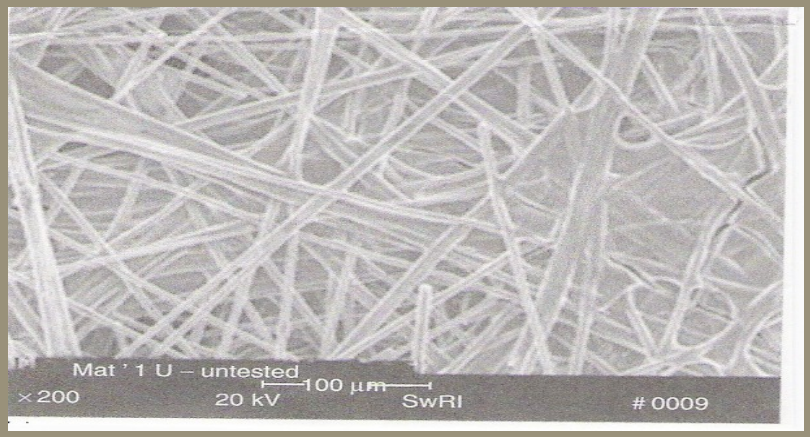
SBIR Review:

- **Concept:**
  - Objectives
  - Introduction – Woven vs Nonwoven fabrics
- **Technical Accomplishments**
  - Achievements
  - Results – Comfort, Durability, Flame Resistance, Water Absorbency and Repellency
- **Programmatic**
  - Schedule – Phase I and Option
  - Funding
  - Overview / Update, Phase II
- **Commercialization**
  - Military and Non Military Markets
  - Summary

Objectives:

- **Utilize nonwoven technology to:**
  - Enhance performance over current USMC woven fabrics
  - Reduce lifecycle costs of USMC combat clothing and equipage
- **Design and develop nonwovens that are:**
  - Light-weight
  - Strong
  - Durable
  - Breathable
  - Cost effective
- Composite fabric designed to obtain different interior vs exterior fiber properties
- Develop Fire Retardant Nonwovens
- Incorporate Chemical Protective active elements to resist chemical and biological agents

Introduction



- **Woven Fabric Magnified**
  - Bigger fibers/ twisted strands
  - Poor insulation, filtration and barrier properties

- **Non-woven Fabric Magnified**
  - Finer Individual Fibers
  - Bonded
  - Better insulation, filtration and barrier properties

Woven vs Non-woven
Fiber to Fabric Manufacturing Steps

Woven Fabrics
(Current Utility Uniform Fabric)

1. Opening
2. Blending
3. Carding
4. Combing
5. Drawing
6. Roving
7. Spinning
8. Creeling
9. Sizing
10. Beam Preparation
11. Weaving
12. Singeing
13. Scouring
14. Bleaching

Spinning Mill

Weaving Mill

Finishing Mill

Non-Woven Fabrics
(Proposed Utility Uniform Fabric)

1. Opening
2. Blending
3. Carding / Web Formation
4. Bonding
5. Finishing

Potentially all under one Roof!

Woven vs Non-woven

Woven Fabrics (current utility uniform fabrics):

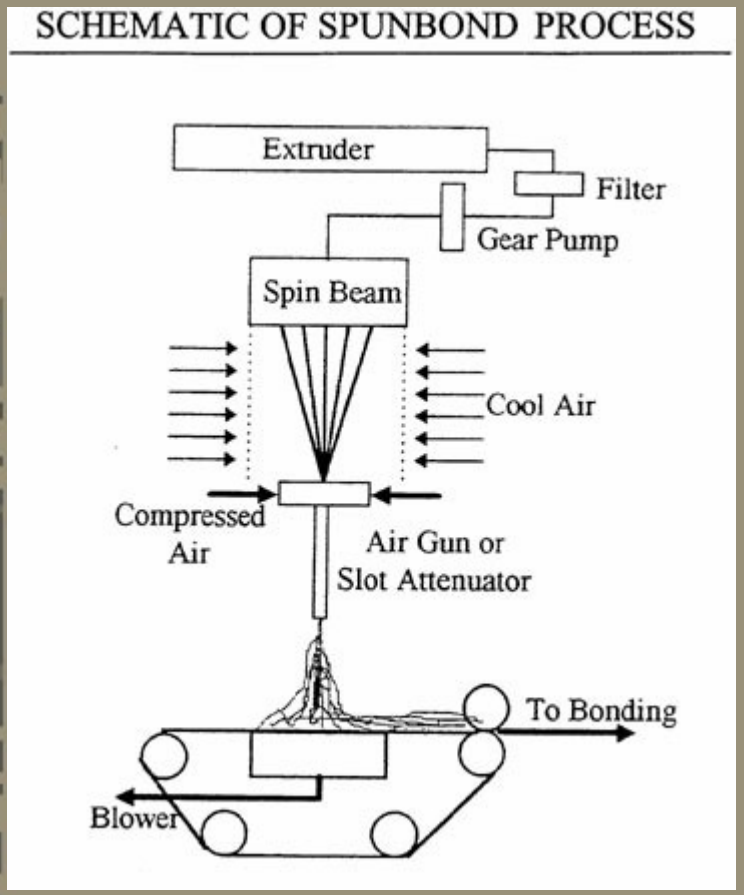
- Old Textile technologies known for centuries
- Outdated and outsourced to other countries
- Not very effective for barrier garments
- Many steps thus Expensive
- Examples – Garment, Furnishings etc.

Non-Woven (not woven from the loom) Fabrics:

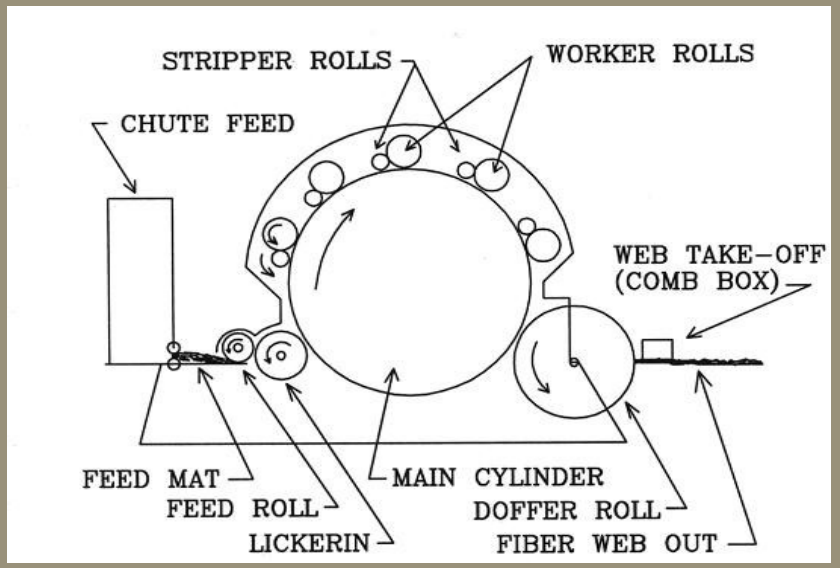
- Only a few decades old, future fabric technologies
- Offer innovation and technological growth for the industries in the USA
- Very Effective for barrier clothing
- Few steps thus Less Expensive
- Examples – Medical Garments, Hazmat Clothing, Automotive etc.

Nonwoven Web Forming Processes

Spunbond Process

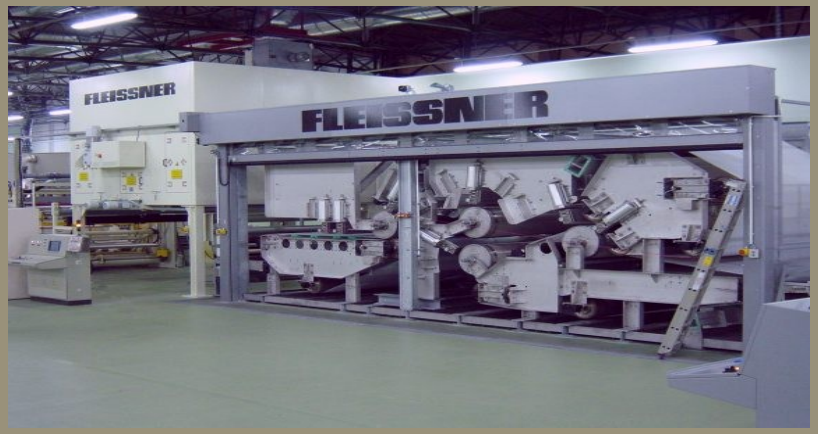


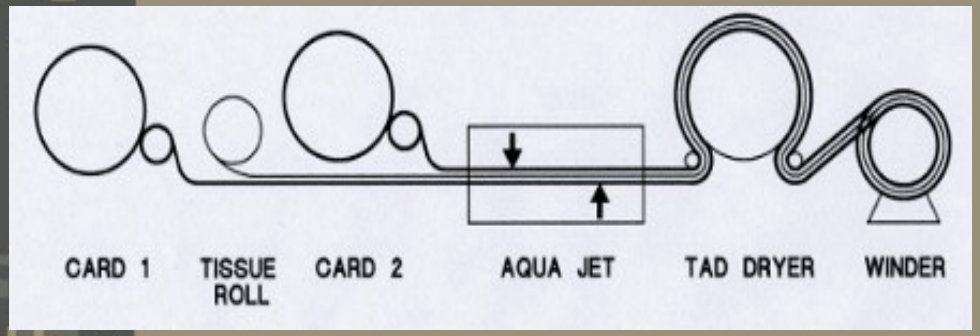
Carding Process



Non-woven Bonding Processes

Hydroentangling and Calendering



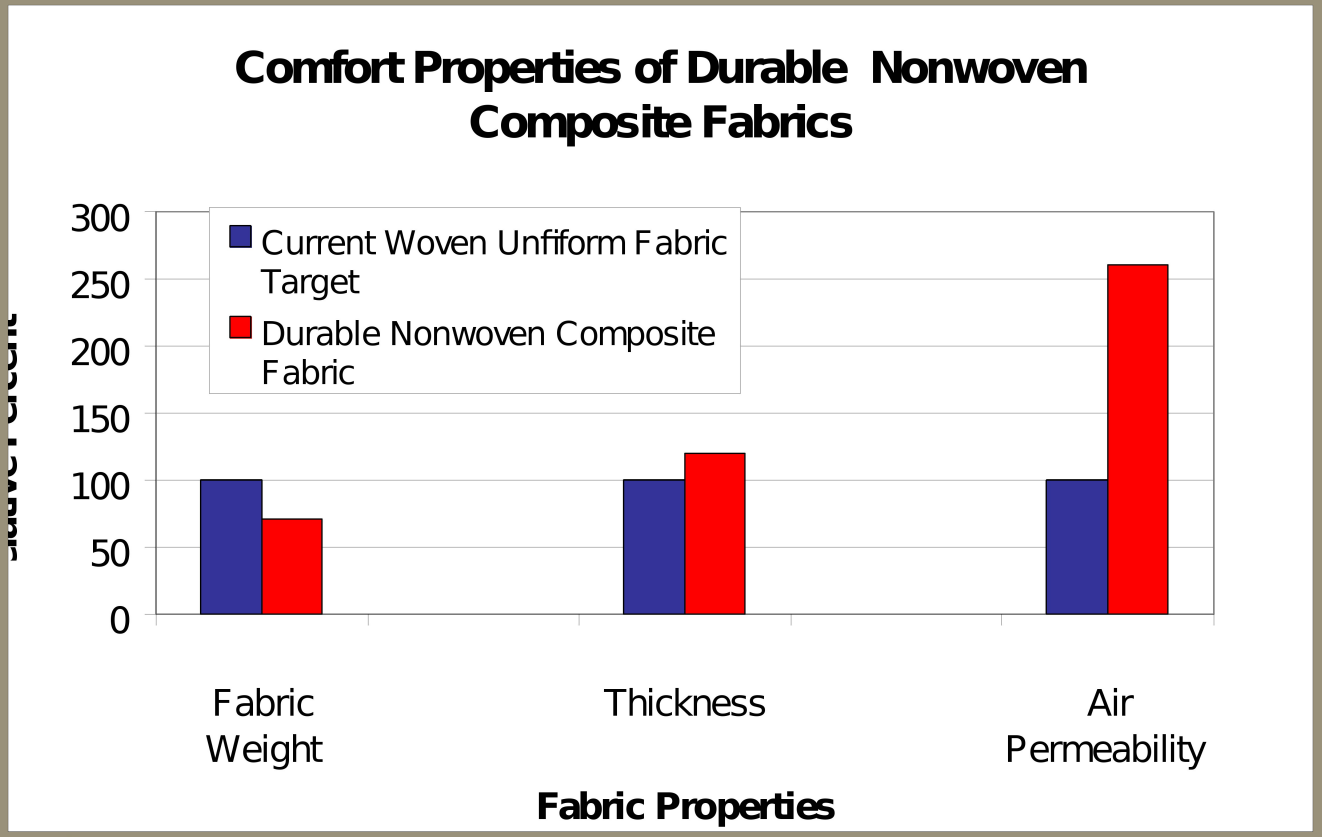


Phase I Achievements:

- Strongest yet thinnest nonwoven composite fabrics
- Extremely lightweight
- Enhanced softness and air permeability
- Demonstrated printability of USMC camouflage pattern
- Composite multilayer composition with enhanced water absorbency inside for sweat absorption and water repellency exterior for rain protection.
- Created fire retardant nonwoven fabric for uniforms and tentage
- Laminated nonwovens with additives for resistance against C&B agents

Technical Accomplishments- Results

- **Nonwoven Apparel Fabric - Comfort**
  - Lighter weight and higher breathability leading to potential reduction in heat stress



Technical Accomplishments- Results

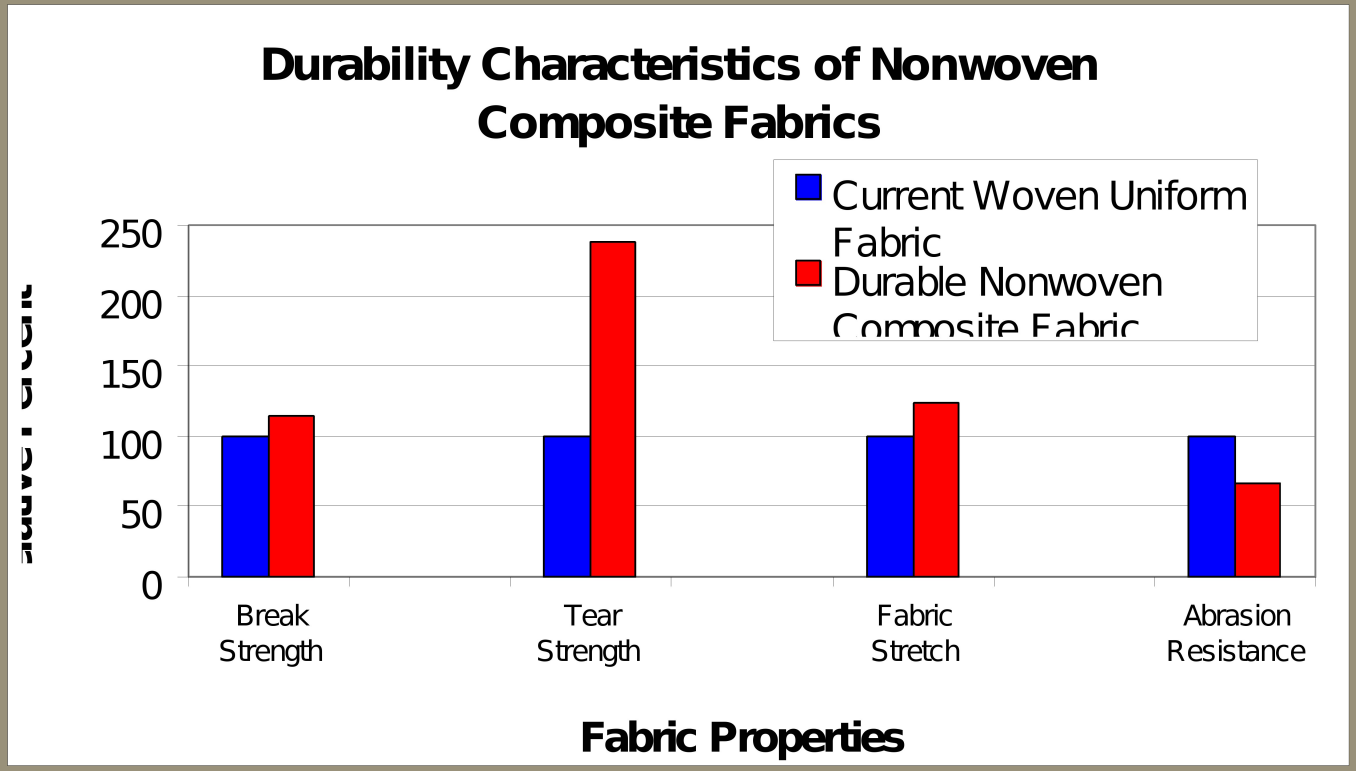
Nonwoven Apparel Fabric – Moisture Transport

- **Sweat Absorbency on the interior layer**
  - Designed the fiber composition for instant wet – out with sweat or liquid on the interior layer or garments
  - Enhances the comfort in hot and humid conditions
- **Water Repellency on the exterior layer**
  - Designed the fiber composition to repel rain water and other fluids on the exterior of garments

Technical Accomplishments- Results

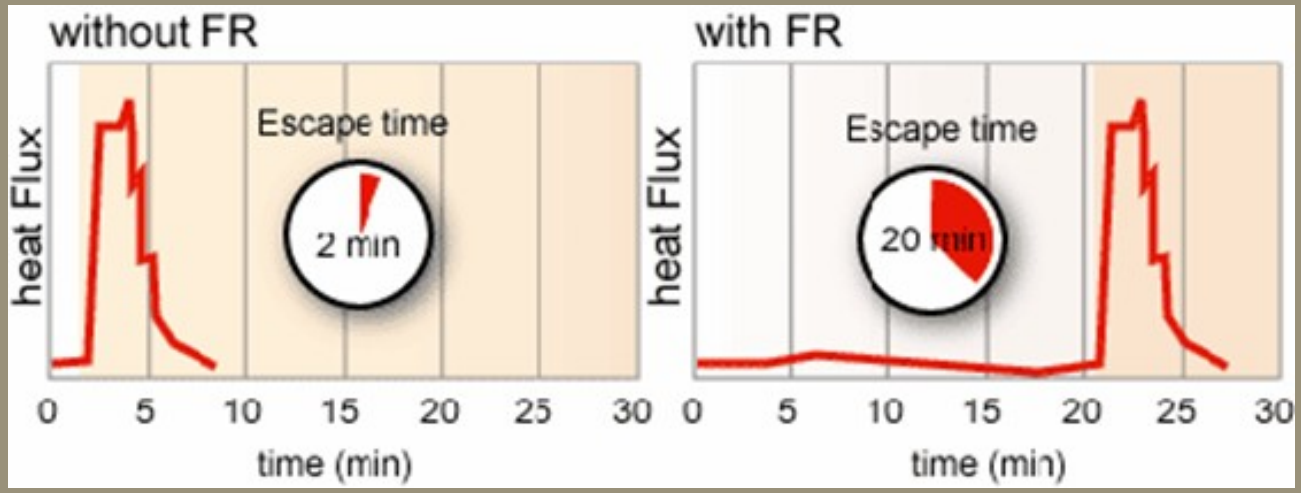
Technical Accomplishments – Results

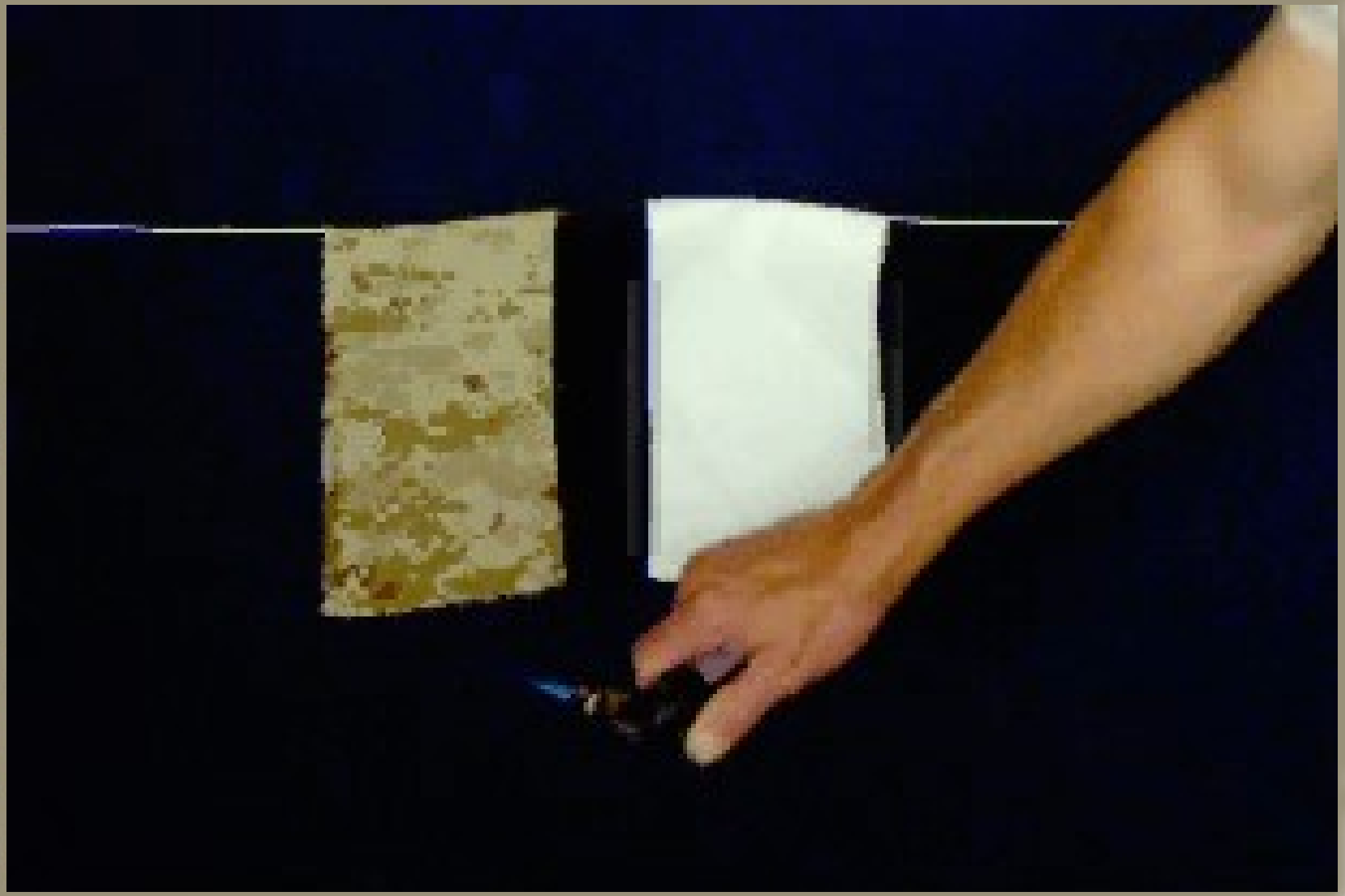
- **Nonwoven Apparel Fabric – Durability**
  - Higher breaking strength and tear strength on a unit weight basis
  - Similar fabric stretch values
  - Slightly lower abrasion values



Technical Accomplishments - Results

- **Nonwoven Apparel Fabric – FR Treated:**
  - Successfully treated the nonwoven composites with fire retardant (FR) chemicals to impart the following characteristics
    - Self-extinguishing - Meets UL 94 V-0
    - Non-Drip
    - Char formation - Low smoke generation
  - Attached video illustrates the performance of Nanosyntex FR treated nonwoven composite fabrics

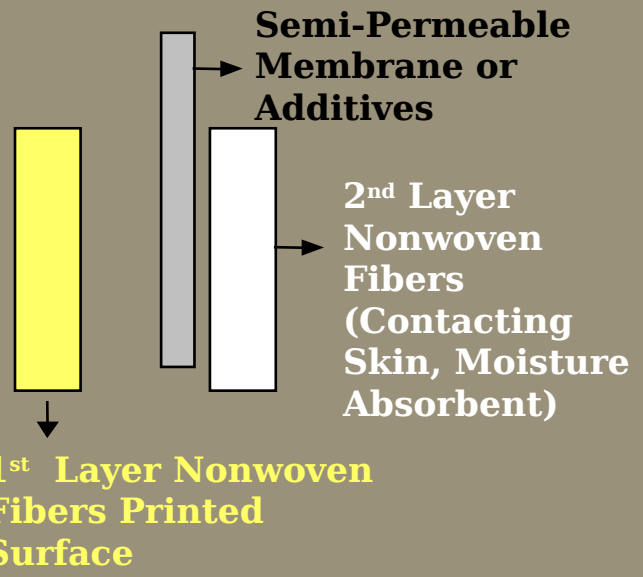




Technical Accomplishments- Results

- **Chemical and Biological Agents Protective Suit:**
  - Activated carbon
  - Other Additives
  - Semi-permeable membrane
- **Tested against methyl chloride gas permeation**
- **Much smaller molecule than nerve agents**
- **Tested current CPU fabric liner**
- **Break-out occurred in less than 1 minute for all fabrics with activated carbon and other additives including the current CPU fabric liner**
- **Over 90 minutes of break-out time for nonwoven composite fabric with membrane**

- **Fabric Construction:**


Semi-Permeable Membrane or Additives
2nd Layer Nonwoven Fibers (Contacting Skin, Moisture Absorbent)
1st Layer Nonwoven Fibers Printed Surface

Phase I Conclusions:

- **Superior Comfort**
  - Light-weight, Enhanced Breathability, Excellent Softness
  - Improved Moisture Transport inside, Water Repellent Outside
- **Outstanding Durability**
  - Higher break and Tear strength to fabric weight ratio
- **Safety**
  - Ability to add Flame Retardancy
- **State-of-the-Art Technology**
  - Modification of properties of various fiber / nonwoven layers
  - In-line continuous production vs. multi-step process of woven fabrics
- **Cost savings**
- **Made in USA**

Phase II:

- **Contract Award – November 2004**
- **Time Line – 2 years**
- **Funding - $574 K**
- **Technical Objective:**

  - Finalize design, structure and optimize nonwoven properties, i.e. abrasion resistance, launderability, etc.
  - Create and field test USMC Combat Utility Uniform prototypes
  - Design and create FR prototypes for USMC application.
  - Optimize CP nonwoven properties

SBIR Commercialization Plan:

- **Highly rated for SBIR award**

- **Market Areas:**
  - Military fabrics for personnel uniforms, tentage and equipage
  - Non military : Outdoor and sporting apparel, workmen clothes and uniforms for first responders, heavy duty tarps, covers, backpacks, etc.

Thank You:

Fleissner for equipment photo

Nanosyntex for SBIR final report slides

USMC for funding and support